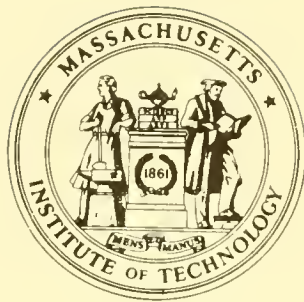
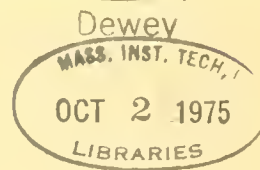
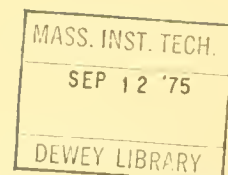


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COMPUTERS AND THE LEARNING PROCESS

John F. Rockart

REPORT CISR-15

SLOAN WP 802-75

August 1975

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FOREWARD

This paper is an atypical C.I.S.R. paper. It is included in the series, however, since it is felt to be of interest to a segment of C.I.S.R. sponsors for the reasons noted below.

The paper was presented at the 10th Educom Fall Conference held in Toronto, Ontario, Canada several months ago and is a summary of the book Computers and the Learning Process in Higher Education to be published by McGraw-Hill in September, 1975. Written by John F. Rockart and Michael S. Scott Morton, the book presents several research results and a resulting framework for the use of computers in higher education developed by Morton and Rockart.

The paper is included in the C.I.S.R. series because:

- (1) Some C.I.S.R. sponsors are computer manufacturers interested in utilizing their products in the area of education. The paper therefore is relevant to them.
- (2) An increasing number of computer-user organizations utilize their on-line systems for internal training and education, and it is hoped that the work is of some interest to them also.
- (3) Finally, it may be of general interest to computer-minded executives -- providing a new slant on a field that is certain to grow -- if slowly -- computers and education.

COMPUTERS AND THE LEARNING PROCESS

by

John F. Rockart

In order to discuss the impact of computers on learning, it is important to understand the learning process -- the manner in which people obtain and assimilate knowledge. I would argue that one must have a working model of the learning process if one is to design computer systems to assist it.

A significant point is that we all do have implicit models of what learning is, and therefore, how computers can assist this process. And each of us uses his or her implicit model when we design computer systems to assist learning. The real need in the field, I believe, is to make these models explicit. Only then can we lay bare the assumptions upon which each of us bases the fundamental design of our computer-based learning aids. These assumptions, as noted later, are critical -- for they hugely influence the type and exact form of the computer tools that we design to assist the learner.

This paper presents some conclusions that Michael Scott Morton and I have come to as a result of reviewing the literature in the field of technology-assisted learning, and also of working in the field for several years (albeit at intervals). A much more expanded version of this paper, which I trust will fill in the many chinks these few pages leave open, will be available soon in the book Computers and the Learning Process in Higher Education, by Michael and myself. This will be published in the Carnegie Commission series on Higher Education.

The search for a precise model of the learning process is a difficult one. Unfortunately, the majority of the published material with regard to the learning process, while intellectually rewarding, is of little assistance

to the designer of computer-based learning aids. What is needed is an operational statement of the learning process -- one that can be acted upon in the design of course materials, the design of a pedagogical strategy, and the assessment of a place of computer technology in that strategy.

A precise "model" enables one to describe and partition the possible impact of various technologies on segments in the learning process. Of equal importance, it enables others to test and offers conclusions about the effects of the technology with reference to the stated model. Finally, others can test the author's conclusions against his own model of the learning process, and determine whether differences in perspective are based on differing perceptions of learning or differing perceptions of technology.

Neither Professor Morton nor I would claim that our particular view of the learning process, and how it can be aided by computers, is "right." Rather, I present here an explicit model of the learning process which we have found operational and useful as a point of departure from which to build systems to aid education.

The State of Learning Theory

Over the years learning has been considered primarily the domain of psychology. Since the mid-1880's when the first really useful work on memory was published (Ebbinghaus, 1895), there has been a series of attempts at explaining learning phenomenon. Unfortunately, many of these attempts have been at or near the level of grand theory and have been in conflict with each other. A good summary of these theories is found in Hilgard and Bower (1966).

In general, two major theories of the learning process have dominated the field through the last few decades. These are known as the stimulus-response (SR) theory, and the cognitive theory. A third major theoretical

approach to learning, that of Piaget, has also entered this field more recently but will not be discussed here. As Figure 1 shows, the two major theories can be separated on three major characteristics. The stimulus-response school (perhaps best known through the experiments and written works of Pavlov and Skinner), suggest that what we perceive as learning is merely a "chained muscular response." In effect, the SR school suggests that people learn habits and learn new things by applying the closest old habit until one fits the situation. If there is no old learned habit that comes close to fitting the situation, one learns through trial and error. The cognitive school, on the other hand, (represented by psychologists such as Tolman and Bruner) suggests that what goes on is really a central brain process in which the learner learns cognitive structures -- similar to computer programs. New things are learned by "insight," which is a process of comparing new situations with old cognitive structures. Exactly how this occurs is unexplained. Clearly, at least to me, the latter theory is somewhat more appealing. Skinner's (1972) writings, which reflect the SR theory, remove all free will from mankind. But personal choice of theory, intuitively or logically, is not important. What is important is the usefulness of these theories in designing learning aids.

Unfortunately, it is almost impossible to use these theories pragmatically. The only viewpoint one can take, and have explicit action flow from it, is a strict SR stance. If one does so, one is thrust in lock-step mode toward the exclusive use of Skinnerian programmed learning. Whether explicitly or implicitly because of this, much of the early work done in the field of computers and learning followed these lines. Yet this approach seems far too single-minded to encompass the entire field of learning with the richness and variation which we believe it holds.

Thus existing learning theory left us somewhat unimpressed. These theories suggested only generalized (and/or single-minded) approaches to the technology. They left too few specific knobs to turn. They failed to suggest specific areas of potential success for learning technology. And they failed to provide guidance for the most useful action steps that could be taken to utilize computers, as opposed to other learning aid, by the individual professor with a particular course to teach.

Dave Kolb, one of our colleagues of M.I.T., has summarized the pragmatic failures of these theories well:

"Because of my early psychological training in learning theory my first impulse was to turn for the answer to these questions to the basic psychological literature on this subject. To my dismay I found that, in spite of the high scientific quality of this work, it was immensely difficult to apply this research on reinforcement theory, discriminative learning and such to the kind of practical decisions involved in the design of university teaching." (Kolb, 1974, p.1).

This same frustration led us to review the work of practitioners in the field of learning, as well as the theorists, in an attempt to elicit a useful learning model. Five sets of critical variables with regard to learning emerged from this search. They are:

- The stages of the learning process
- The characteristics of the material to be learned
- The characteristics of the learner
- The characteristics of the teacher
- The learning environment

Of these five categories, the first two appeared most significant for our purposes. The last two are very complex variables which we found terribly difficult to model. At the time of the development of our model, also, the characteristics of the learner -- the third variable in the above list -- was not as well researched as it is at the time of the writing of this paper. Therefore, it was not included.

We thus limited our modeling of the learning process to two variables -- the two that seemed to us (1) significant, (2) operationally describable, and (3) least apt to be changed by the conclusions from the study. These two variables are the "stages of the learning process" and "characteristics of material to be learned."

The Stages of the Learning Process

The search for an operationally useful statement of the learning process is not an easy one. We finally centered on a model developed by behavioral scientists -- but one which could be generalized to the learning process in all fields.

The behavioral approach to describing the learning process which serves as the basis for our own model follows the work of Kolb (1971). Reacting to the frustration of the inapplicability of learning theory for the practical educator, and needing something to guide his efforts in the educational process, Kolb turned to the so-called experiential learning model (Figure 2) -- a model that, adapted somewhat, we have used as the core of our work. Developed primarily out of the experience of sensitivity-training practitioners (Schein and Bennis, 1965), the model has gained increasing acceptance as a framework for the design of learning programs. It has been used in such diverse areas as education (Miles, 1965), the incident process in management training (Pigors and Pigors, 1963), Peace Corps training (Wight, 1969), and self-assessment (Katz, 1970).

In this model, learning is conceived of as a four-stage cycle which translates experience into new concepts. Immediate concrete experience (step 1) is the input to step 2 where the meaning of the experience is embedded and "understood" through observation and reflection. In step 3,

these observations are assimilated into a "theory" or conceptual basis from which new implications for action can be deduced. Finally, these implications are tested in the real world in new situations (step 4). In turn, the testing process leads to a need for new concrete experiences themselves -- and the loop is closed.

It is important to note that the experiential learning model depends on the learner undergoing some sort of experience that provides an initial set of facts or feelings as input to the learning cycle. It is clear, however, that most of what is learned in college is not based on an initial experience, but rather on the acquisition of new facts or skills. The behavioral model, however, can be generalized without too much difficulty. In this more general form, the model appears as in Figure 3.

The initial stage of this more universal learning model is the initial acquisition of basic components of knowledge by the student. Here the learner is exposed to, and asked to comprehend, basic data, skills, or concepts that will be put to use in later steps.

The second stage is the "salting away," or embedding, of this knowledge by the learner. In this stage, the student "practices" and ponders his new skills. He may perform homework exercises to see if he has understood the new facts and how to apply them. He may actually use the skills in the performance of a task. Or he may merely think through the facts, skills, or processes he has learned.

The learner then moves to the third stage of this general model -- a stage in which the new ideas assist in the development of a new conceptual grasp of the world. This is an integrating phase in which the student moves from the rote acquisition of material to its incorporation and subjugation into more global conceptual structures. It is the stage in which the learning of new things "pays off" in new understanding. New mental models of the universe, or parts of it, are formed. Robust platforms, on the basis of which action can be taken, are constructed.

The testing of these new conceptual structures is the final phase. It is a phase at which the cycle is often broken in formal, university-level education because today there are few pedagogical mechanisms available to the student by which he can test the implications of his new understanding. The richness of the learning process is broken, too, as new conceptual bases are learned, and then stored away to gather dust. Stage 4 is clearly more often reached in courses run along experiential lines, in short "executive" programs -- or in courses allowing access to a pseudo real-world environment, via simulation models, for example, a point to which we shall return later on.

This general model of the stages of the learning process is, I believe, a useful, and conceptually sound, way of looking at our first variable -- the learning process.

The Material

Let us now turn to the second major variable considered in our learning model -- the material. Many different categorizations of material can be presented. The problem is to provide a set that is meaningful throughout most disciplines and that can be utilized to describe each learning area in an operationally useful way. One such categorization commonly used in the learning literature that we have found to be both applicable to various disciplines and useful in its description of their material, is as follows:

Facts, including definitions and other basic information relating to specific single items or ideas.

Skills, including both procedures and rules and their applications.

Established concepts, as well as other theories, hypotheses, postulates or assertions that are well enough established to be of no interest to the current researchers in the field. "Concepts" use "facts" as basic building blocks in constructing the concept.

Frontier concepts, including not only recent developments but also long-standing issues which either have not been, or cannot be, resolved.

For any particular course or department, this breakdown of material can easily be further divided. Category 2 (skills) can (perhaps should) be broken down into several highly distinct types of skills. Indeed it is necessary to subdivide these categories further when dealing with a particular course.

But, across courses and departments, we find that this four-part categorization serves as a good vehicle for understanding the applicability of technology to particular curriculums. We found it meaningful to several of our colleagues who were able, in a survey, to easily classify the material taught in their courses within the bounds of this classification.

It does not take much imagination or deep thought to hypothesize that the relative emphasis on these four categories of material will vary with particular university departments and with differing degree-level programs (e.g., undergraduate, master's, doctoral). This, in turn, will mean that the type of learning technology that can be effectively employed will also differ from course to course. The type of learning technology that can be effectively employed will therefore also differ. Yet the four classes of material appear to be a reasonable division of material types.

An Operationally-Useful Learning Model

Our basic learning model, then, has two variables -- learning stages and material classes -- that together produce 16 cells as shown in Figure 4. It is this two dimensional structure which must be confronted when asking the question as to where the computer fits in the learning process. The process involved in learning in each of the cells is different, we submit; and the technology utilized must be fitted to these differences. Therefore, the computer fits in differing ways into each of these cells; in some it is not very useful at all today.

The fundamental proposition this suggests is that one cannot think of the use of "the computer in learning" as a whole without doing a great disservice to the variety of material and the complexities of the differing stages of the learning process. The computer must be expected to be utilized in different modes in each area (or each cell of the model shown in Figure 4). Some of the cells, I would submit, are almost impregnable by "computer aids to learning" as they are currently available today. Others are ripe for differing types of computer assistance to the learning process.

We now have before us a learning model divided into 16 cells. The following sections (1) briefly note the many "learning aids" available to assist learning, (2) analyze the learning demands of each of the cells of the learning model, and then (3) attempt to match the appropriate technology to these demands. In this paper, because of space and time, this is done in a very cursory manner. The process is much more fully explicated in our book.

Learning Aids. It is clear that today we have a large set of available mechanisms to assist learning. These include the professor (who can lecture, lead a class discussion, etc.); books; video tape; computers (which can be used in tutorial mode (more commonly called "programmed Instruction"), for drill and practice, for gaming, simulation, etc.). Each of these mechanisms can be rated as to its effectiveness on a well-defined set of attributes. For example, some mechanisms are very economical per fact presented. Some have the attribute of decentralized availability -- text books have this; computers in most cases today do not. Other attributes such as emotional impact, sensory impact, the ability to telescope time, etc. are possessed to a greater or lesser extent by each learning mechanism. We have defined a set of sixteen of these attributes (Figure 5) and find that

the learning aids available today vary widely along many dimensions with regard to each of these attributes. The major learning aids and our ranking of them on each of the sixteen attributes (where 1=high and 10=low) are shown in Figure 6.

Learning "demands" of Each Cell. The matrix shown in Figure 4 suggests that the 16 cells are each somewhat unique and thus that the type of learning that takes place in each cell requires differing types of learning assistance. Just as the learning aids noted above have different attributes, the cells of the learning matrix need different types of learning assistance -- and must be matched by the choice of that(those) learning aid(s) which best fit these needs.

Four examples may best illustrate the concept of matching the correct learning aid with the learning process requirement of each particular cell. The upper left cell of the matrix (the acquiring of facts) has two key learning attributes needs as shown in Figure 7. There are many facts to be learned, therefore, the learning tool which aids this learning should therefore be (1) cheap, and (2) available whenever and wherever the student wishes to turn this learning process. Clearly the learning aid which ranks high on these attributes (#15 and 16, and from Figure 5) is the textbook. Relative to all the other learning aids it is clearly dominant at the present time with regard to economy of presentation of facts and decentralized availability.

Moving to the lower left corner of the matrix, a different situation exists with regard to the acquisition of frontier concepts. Here one is looking for a learning aid which can structure ill-structured material for the learner, is able to promulgate new material in a timely way, and can easily adjust to individual needs with regard to ill-structured material. The dominate learning aid here is clearly the professor, most probably in lecture or class discussion mode.

Now let us shift to the lower right-hand corner of the matrix. For the testing out of frontier concepts in areas other than the one in which they were learned, it is clear that the learner needs the availability of a large data base, methods of manipulating this data base, and -- highly desirable -- a method of "trying out" the concepts in a way which does no harm to anyone. This testing out process has been done in the past in the "real world" quite often resulting in some damage to both the testees and the testor. We would suggest that the ideal learning mechanism for this cell today, is not the real world as a test ground, but rather computers and simulation models. In this way the student can adequately test out his ideas in a simulated world if he has access to enough data and enough computing power. The learning aid of choice thus becomes computers.

Moving back to the second cell from the left at the top of the matrix, in order to embed facts, there is a need for feedback to the learner -- as immediate as possible -- in order that he can know how well he has performed on answering questions which test whether he has or has not acquired the facts which he is supposed to have learned. This is usually done today through "homework." Unfortunately, the lag in time from the point of which the student completes his homework to the time he receives written feedback from the professor or teaching assistant is often quite long. It is also desirable if there is "learner control" (the ability for the learner, for example, to omit imbedding exercises on material he has previously learned) associated with the homework process. Under current paper and pencil methods, this is difficult to do as the learner usually is required to perform all of the exercises given. A computer-based "drill and practice" interactive system in which the student is "tested," allowed to answer, and given immediate feedback as to the correctness of his answer, is much the preferable mechanism in this cell. With continuing decreases in computer costs, we expect that it will, in the relatively near future, become the mechanism of choice for embedding facts, skills, etc.

This discussion of "matching" appropriate learning aids to the need of each cell can be generalized somewhat to develop groups of cells which will benefit from the same general treatment. Figure 8 suggests this generalization. Five distinct areas are shown. We believe that area I belongs primarily to the textbook. As a generalization, the area II belongs either to paper, "homework exercises," or computer drill and practice as learning aids. Area III is best assisted by computer-based drill and practice or computer-based problem-solving methods. The area shown as IV is best assisted through computer simulation or games as the arguments suggested for the lower right hand corner of Figure 7 have noted. Finally the area marked as V is the province of the professor.

It can be seen that some of the cells are overlapped by two or more general areas of learning assistance. And some of the cells are left blank. This suggests that there are multiple learning aids possible in these particular areas.

Summary and Some Implications

What has been presented is a generalized model which matches varying learning aids to the needs of the learning process. A two variable, 16 cell model of the learning process has been presented. This framework has been useful to us in our design of courses and in our choice of learning aids to assist students in comprehending varying types of material at varying stages of the learning process (Rockart, 1973). The model suggests places where the computer dominates as a learning aid. It also, and perhaps more importantly, suggests places where other learning resources dominate in the learning process.

The model presents, therefore, our explicit model as to the types of computer-based learning assistance which should be allocated funds from increasingly scarce higher education dollars at the present time. It should be noted that our model suggests that the computer-based "tutorial" instruction (better known as Skinnerian-type "programmed instruction")

which is usually used for the transmission of facts should not be a priority area for the allocation of funds at the present time. (There are, of course, exceptions to this rule. One is in cases of an exceptional need to motivate students, such as in the case of retarded students, or the need to rapidly assimilate particular vocabularies.) In general, however, our model suggests that computer-based tutorial methods suffer hugely by comparison with traditional textbooks for the acquisition of facts. The model is therefore in conflict with much of today's government funding of computer-based learning aids. However, a survey of computer use to aid learning in higher education in the state of Massachusetts suggests that where professors are voting with their institutions' own dollars, they are in heavy agreement with what our model suggests. (See our book, Chapter 7). There are virtually no tutorial programs being utilized which were developed through non-government funds... at least in Massachusetts. Rather money is being spent to support computer-based aids to embed (drill and practice programs) material, integrate material, and allow students to test ideas in simulated or gameed environments.

Finally, I would argue that an explicit statement of the learning model that underlies the use of computer systems to aid education is a useful thing in itself alone. It is helpful if one never touches a computer for the insights it provides into learning -- and, therefore, teaching. On the other hand, it can be even more helpful in specifying the correct tools to assist learning and particularly in allocating increasingly scarce higher education dollars toward areas where the computer can be of the most help in assisting the learning process.

	<u>STIMULUS-RESPONSE</u>	<u>COGNITIVE</u>
<u>PROCESS TYPE</u>	CHAINED MUSCULAR RESPONSE	CENTRAL BRAIN PROCESS
<u>WHAT LEARN</u>	HABITS	COGNITIVE STRUCTURES
<u>NEW THINGS</u>		
<u>LEARNED BY</u>	APPLYING CLOSEST OLD HABIT -- OR TRIAL AND ERROR	"INSIGHT" -- COMPARISON WITH OLD STRUCTURES

FIGURE 1

Basic Differences in Two Major Learning Theories

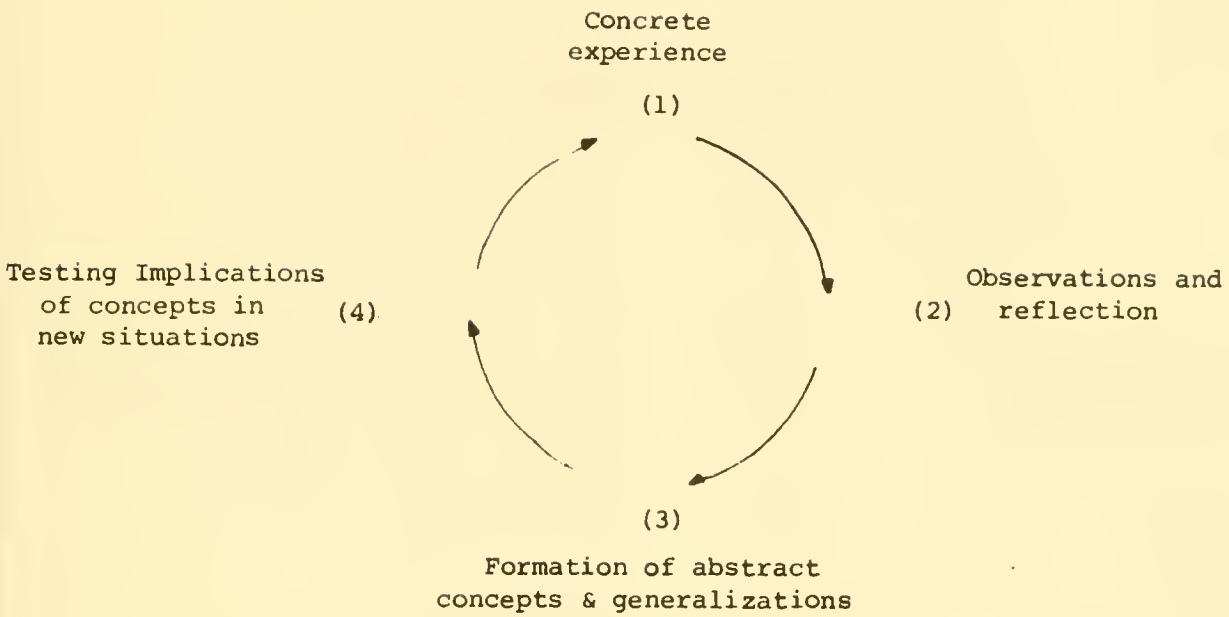


FIGURE 2

The Experiential Learning Model

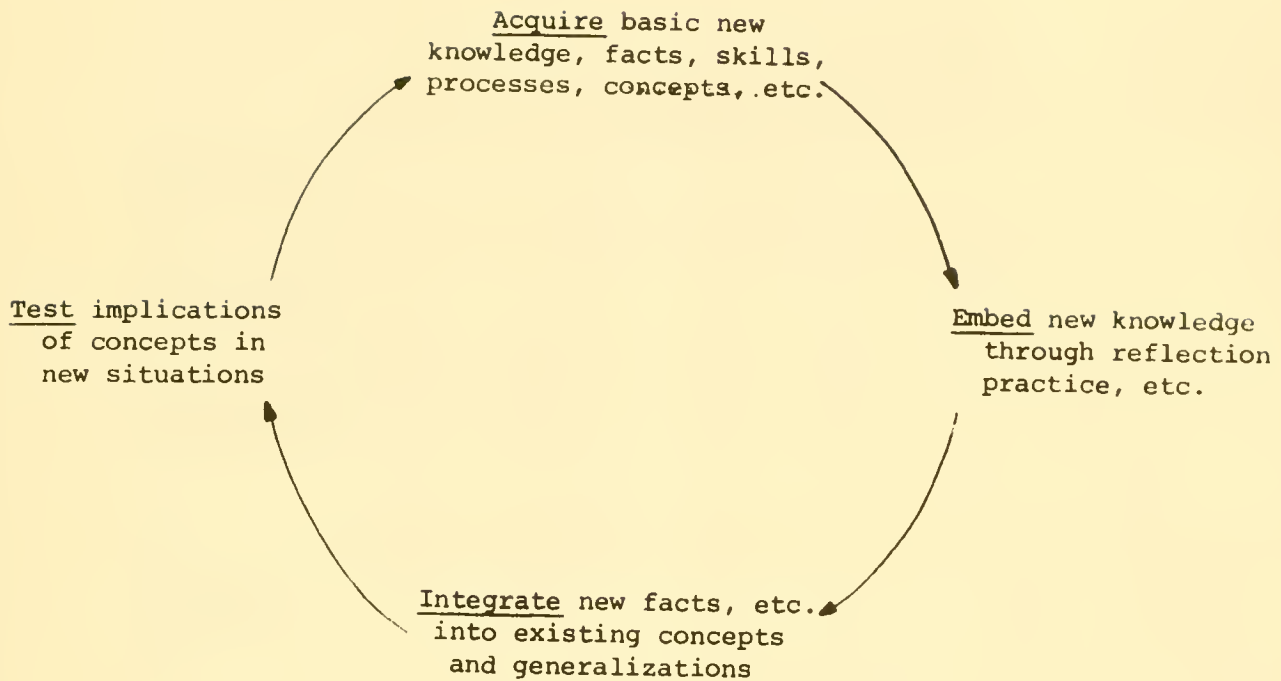


FIGURE 3

A General Learning Model

	Acquisition	Embedding	Integration & Generalization	Testing in New Studies
Facts and Definitions				
Skills and Procedures				
Established Concepts				
Frontier Concepts				

FIGURE 4

A Learning Matrix

I. Content Related

1. Ability to telescope time
2. Ability to present structure
3. Provision of a rich environment
4. Ability to provide ill-structured material
5. Flexibility for adding new material quickly
6. Support for the learners' structured, clerical tasks
7. Support for unstructured data manipulation

II. User Related

8. Degree of learner control
9. Ability to adjust to individual learner needs
10. Ease of use

III. Communications Related

11. Amount of sensory impact
12. Amount of emotional impact
13. Degree of learner feedback
14. Ability to access data or concepts previously learned

IV. Economics

15. Low cost per data item or concept
16. Decentralized availability

FIGURE 5

Summary of Attributes of Learning -- Delivery Mechanisms (Tools)

Mechanism	Content						User			Communication				Economics		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
AUDIO																
Lecture	5	3	8	1	1	10	10	8	1	5	5	3	8	10	3	8
Case Disc.	5	10	3	3	5	10	10	8	5	5	5	5	8	10	5	10
Class Disc.	5	10	3	3	1	10	10	8	8	5	5	5	3	10	5	10
Tape	5	5	8	5	3	10	10	5	10	5	5	5	10	5	5	3
Radio	5	5	8	5	3	10	10	10	10	3	5	5	10	10	5	3
VISUAL																
Visual Aids	5	3	10	10	1	8	10	10	8	5	3	5	10	8	5	10
Film	1	3	5	1	10	8	10	8	10	8	1	1	10	8	8	5
Video Tape	1	3	5	1	5	8	10	8	8	8	1	1	10	8	8	5
Cable TV	1	3	5	1	5	8	10	10	10	5	1	1	10	10	8	3
WRITTEN																
Text Books	5	3	8	3	10	10	10	10	10	1	8	8	10	5	1	1
PI	10	5	10	10	8	10	10	10	8	1	8	10	3	8	3	1
Study Mods	10	3	10	5	8	8	10	8	8	3	8	8	5	8	3	1
Written Assn	10	5	10	10	5	10	3	8	8	1	8	8	3	9	10	1
COMPUTER																
Tutorial	10	5	8	10	8	10	10	5	5	5	8	10	3	5	5	3
Drill Pract.	3	5	8	8	8	3	5	3	5	5	8	8	1	5	5	3
Prob. Solv.	1	5	5	8	8	3	1	3	3	5	8	8	1	3	8	3
Inquiry	8	8	1	1	8	5	8	1	3	5	5	8	5	1	10	3
Simulation	1	5	1	1	8	1	1	1	3	5	3	5	3	3	10	3
Games	1	5	3	1	8	1	3	3	3	5	3	3	5	5	10	3
OTHERS																
Expts Lab	5	5	1	10	8	10	10	3	10	8	5	8	1	10	10	10
Expts Real	10	10	1	10	5	10	10	3	5	10	3	3	5	10	10	8
World																

FIGURE 6

	Ag.	Em.	I	Test
FACTS	COST DECENTRALIZED AVAILABILITY	FEEDBACK some learner control		
SKILLS				
ESTABLISHED CONCEPTS				
FRONTIER CONCEPTS	ADD NEW MATERIAL structure ill structured material ADAPTABLE			DATA BASE MODELLING ABILITY MANIPULATION ABILITY

FIGURE 7

Significant Learning Aid Characteristics "Demanded" by Cell

- I Textbook
- II Paper or Computer
- III Drill and Practice or Problem Solving (Computerized)
- IV Computer Simulation, Games
- V Professor

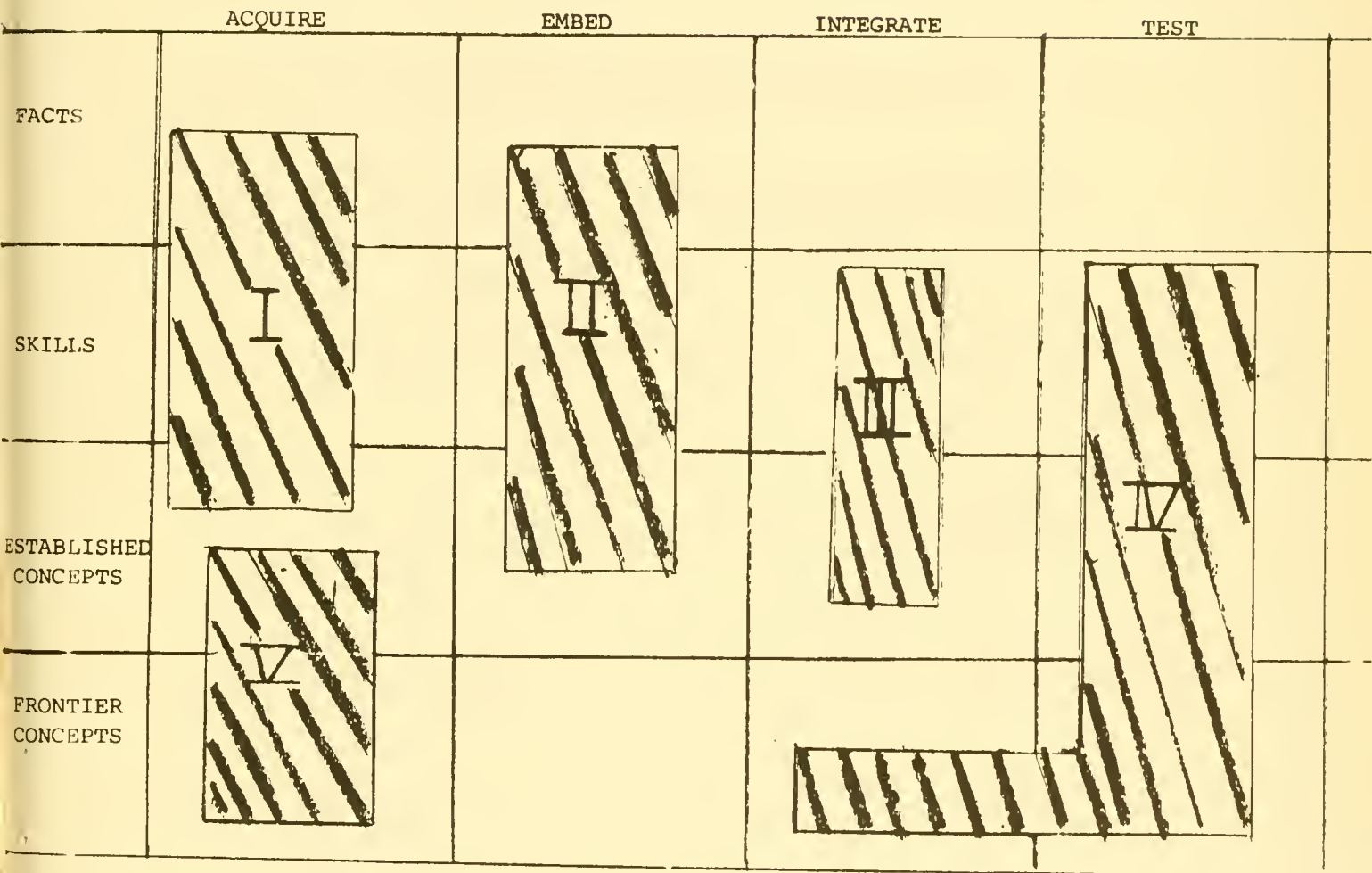


FIGURE 8

Attribute Groupings by Stages in the Learning Process

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